EVALUATION OF GROUNDWATER QUALITY IN COASTAL CITY – A CASE STUDY

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ABSTRACT

The coastal city of Kakinada is a part of river Godavari eastern delta system in Andhra Pradesh. The area under the study is around 85 km^2 and it has the coast length of 8 kms along the Bay of Bengal. Total 164 groundwater samples were collected from 29 dug wells (Depth < 5mts) and 16 filter points (Depth 5 to 7 mts.) during different seasons and analyzed fgr Temp. pH, EC and major anions (HCO_3, Cl, SO_4, PO_4) and major cations (Ca, Mg, Na, K). The quality of groundwater is hard to very hard, but it is suitable for irrigation purposes. Based on SAR and %Na the study area falls under medium hazard of sodium. The comparison of water quality parameters with ISI maximum permissible drinking water standards gives an indication that it is always better to tap groundwater through filter points in the study area, especially for drinking water purposes. The high value of SO_4/Cl ratio indicates the impact of fertiliser use in the study area. The analysis of NO_3 content in the month of November 99 (Well Nos. 1 to 29) confirms the high Nitrate content in the study area. The high Nitrate content is not only due to fertiliser use and it may be also due to high density of septic tanks in the town. The groundwater flow direction in the study area is towards saltcreek and Bay of Bengal.

1-0 INTRODUCTION

Maintenance of groundwater quality at an acceptable limit is a major requirement for successful use of a groundwater reservoir. Impervious materials form localized barriers to groundwater movement and prevent uniform dispersion of water throughout the aquifer. As a result, considerable variation in groundwater quality under natural conditions can be expected to occur in the various parts, both spatially and in depth of the groundwater reservoirs. The contamination due to man has occurred for centuries, but urbanization, industrialization and increase in population density have greatly aggravated the problem of water quality especially in urban areas. Therefore, on regional scale, an assessment of groundwater quality through regular monitoring is very much necessary to identify the contamination levels.

Gibb et al (1981) and Grisak et al (1978) had explained technical difficulties involved in 'Representative' sampling of groundwater in a region. Hirschberg,K.J.B and Appleyard,S.J (1996) have conducted a baseline survey of non point source groundwater contamination in the Perth basin, western Australia using SO_4/Cl ratio and concluded that agricultural land use is effecting groundwater quality in some areas of Perth Basin, particularly those areas with intensive agriculture where there is heavy fertilizer use, and where the water table is shallow. Satyaji Rao et al (1995, 96) have analyzed groundwater samples collected in Kakinada coastal aquifer and concluded that the TDS, Cl and Na concentrations are increasing towards the sea coast and TDS, HCO_3 contents have exceeded the maximum permissible limits of ISI drinking water standards.

The present analysis of samples collected from the study area may act as a benchmark of groundwater quality of the coastal aquifer and also the information obtained from the study may be useful for local people, Municipal, Environmental and Public health departments. Prior to this study, the information on ground water quality in the Kakinada coastal aquifer mostly limited to one or two wells, which are being monitored by A.P. State Groundwater Department and CGWB. Therefore, the present study is expected to provide useful information on regional groundwater quality.

2.0 STUDY AREA

The coastal city of Kakinada is a part of river Godavari eastern delta system in Andhra Pradesh. The area under the study is around 85 km^2 and it has the coast length of 8 kms along the Bay of Bengal. The study area is located between $82^0 10'$N to $82^0 17'$ N latitude and $16^0 55'$E to $17^0 1'$ E longitude. The main geology of the area is alluvium. The location map of the study area is shown in Figure 1. The availability of natural gas in abundance at distance of 60 –70 Km in Krishna–Godavari basin acts as one of the factors which is fuelling the rapid industrialization and thus makes more stress on natural resources.

3.0 METHODOLOGY

To evaluate the overall contamination levels or hydrochemistry of the shallow groundwater in Kakinada coastal aquifer, total 45 wells have been considered within the area of 85 Km^2. Among which 29 were dug wells (Nos. 1 to 29) and 16 were filter points (Label A to P). Groundwater samples collected from dug wells are at the depth of 2 to 5 mts and from filter points are at the depth of 5 mts to 7 mts from the ground level. The depth of the water table is one of the major factors that may influence the groundwater quality. The sampling survey was conducted in the month of Feb.97, May 97, Aug.97 and Nov.97. The samples of filter points in the month of Feb.97 could not be collected. Total 164 groundwater samples have been analyzed for Temp, pH, EC and major anions (HCO_3, Cl, SO_4, PO_4) and major cations (Ca, Mg, Na, K). These quality parameters are compared with ISI drinking water standards. All samples were classified according to Stiff (1951), Pipers (1953) and U.S. Salinity Laboratory classification (Wilcox, L.V, 1955) and observed their seasonal changes. In each well Total Hardness (TH), Sodium Absorption Ratio (SAR), Percentage of Sodium (%Na) and SO_4/Cl ratio have been calculated.

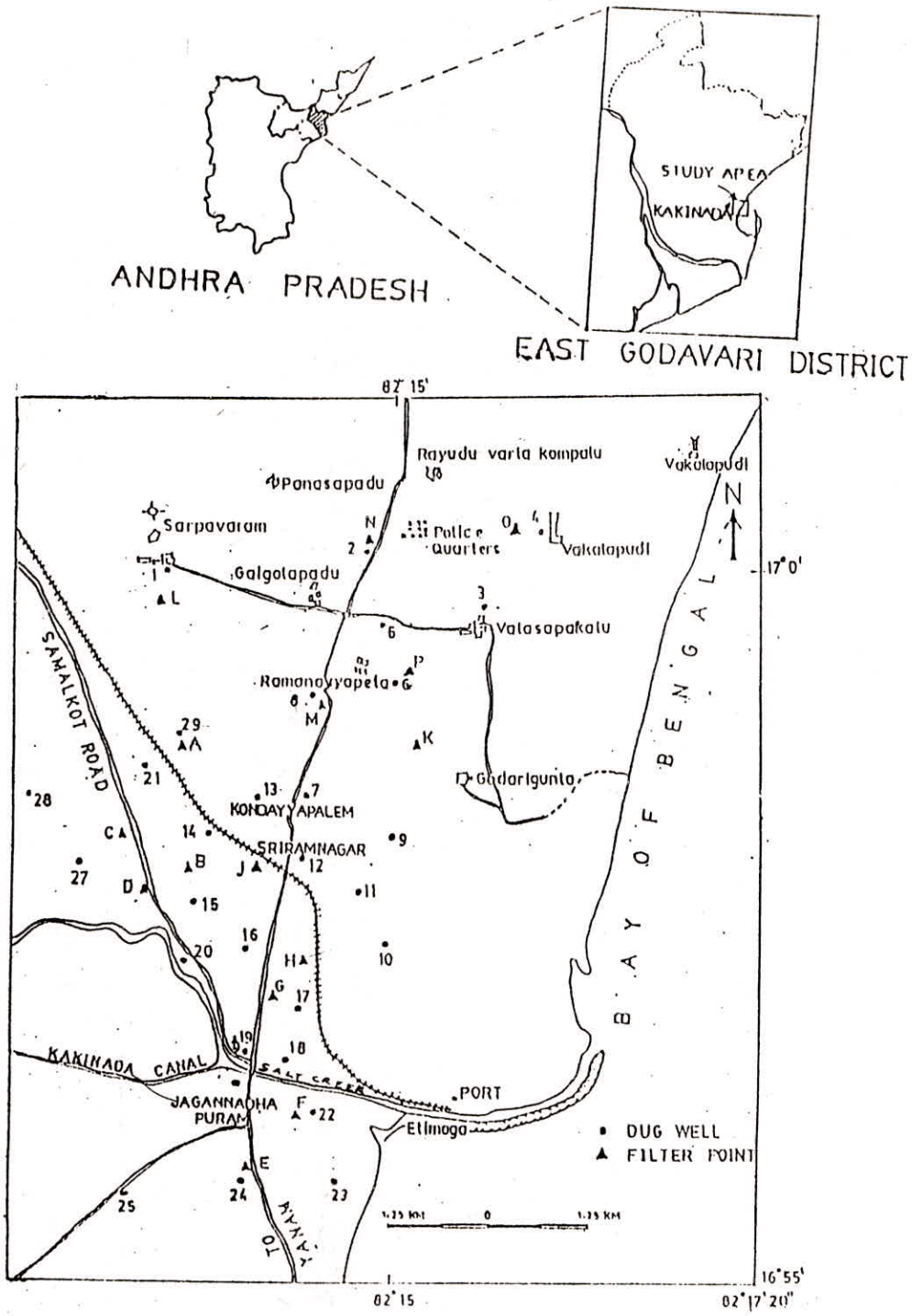

Fig. 1 : Location of Observation wells (Dug wells + Filterations)

The deviation of SO_4/Cl ratio from 0.25 indicates the impact of fertilisers use on groundwater (Hirschberg, K.J.B, 1996). Due to non-availability of Nitrate analysis data in the year 1997, the data of Nov. 1999 is considered for evaluation purposes. Monthly groundwater levels were also measured in 29 shallow observation wells (Dug wells) spread in and around Kakinada town. The groundwater table contour map during the month of April 97 is prepared and approximate flow direction in the study area was demarcated.

4.0 RESULTS AND DISCUSSIONS

The average results of physical and chemical analysis of samples collected from dug wells and filter points in the month of Feb.97, May 97, Aug.97 and Nov.97 are given in Table 1. The average values of TH, SAR, %Na, SO_4/Cl ratio and NO_3 in the month of Nov.99 are also given in the Table 1. Satyaji Rao, Y.R et al (1997) had presented the complete analysis of each period. Measurement of Electrical Conductivity (EC) in observation wells varied considerably even in regional level (312 to 3333 μmho/cm). The variation in EC values may be due to the number of chemical process controlling EC in groundwater in the region and also the effect of local environment of the well. The comparison of hydrochemistry of dug wells and filter points is given in the Table 2. The comparison shows that the quality of groundwater is better in filter points than in dug wells. Therefore, there is significant vertical variation of groundwater quality in the study area. It is also observed that most of the people in the study area are tapping groundwater through filter points for drinking water purposes. The TDS, HCO_3 and NO_3 contents have exceeded the ISI permissible limits in Dug wells. However, these parameters for most of the filter points samples in the study area are within the limits. Further, it is also observed from the Table 2, that the seasonal changes in water quality parameters are more in dug wells than in filter points.

The Stiff, Piper's and US Salinity laboratory classifications of water samples during pre monsoon (May 97) and post monsoon (Nov.97) periods are given in the Table 3. . The dominant cation and anion in the study area is Sodium and Bicarbonate respectively. The major hydrochemical facies in the study area is mixed $CaNaHCO_3$ type. The quality of groundwater is suitable for irrigation purpose (C2-S1, C3-S1 and C4-S1) i.e-medium salinity and medium SAR. The seasonal changes in water types shows the mixing process in the groundwater. The range of SAR (0.6 to 7.5) and %Na (19 to 76%) indicates the medium hazard of Sodium in the study area. According to hardness classification the study area falls under hard to very hard zone (107 to 884 ppm). Consumption of very hard water has impact on human health. The deviation of SO_4/Cl ratio from 0.25 indicates that the groundwater has been affected by fertilizer use. The analysis of Nitrate content in the dug wells during the month of Nov.99 indicates that the high concentrations are not only due to the affect of fertiliser use, it may also due to high density of septic tanks in the town. There is no systematic sewage disposable system in the town. The rapid urbanization of the tgwn may aggravate the problem of high Nitrate in future. Therefore, it is necessary to monitor Nitrate concentrations and identify their sources in the study area.

The spatial distribution of groundwater levels in the month of April 97 are plotted and shown in Fig.2. The range of groundwater table varies between 0.2 mt to 3.8 mts (above MSL) in the study area. The flow direction in the study area is towards salt creek and Bay of Bengal.

Table 1 : Average Ground water quality parameters in the observation wells during the year 1997

Well No / Label	Temp °C	pH	E.C µ.mhos/cm	Ca ppm	Mg ppm	Na ppm	K ppm	HCO_3 ppm	Cl ppm	SO_4 ppm	PO_4 ppm	TDS ppm	T.H ppm	SAR	%Na	SO_4/Cl	NO_3 ppm
1	28.25	7.13	1657.5	145.3	58	128.8	74	337.5	250	140.9	1.88	1062	601.3	2.29	38.68	0.5585	227
2	28.5	6.96	872.5	66.24	18.5	116.3	19.5	264	146.5	70.38	1.09	559.3	241.5	3.28	53.74	0.4476	19
3	28.5	7.08	2957.5	110.8	70.9	408.8	196.3	715.5	467.5	221.3	1.09	1895	568.4	7.53	66.97	0.4821	208
4	28.25	7.29	1915	117.1	49.5	316.3	31.75	577.8	339	85.75	0.75	1227	495.8	6.14	59.02	0.2463	25
5	29	7.09	1140	88.67	23.9	117.5	76.5	316	118	84.38	3.5	730.5	319.6	2.9	52.35	0.7298	100
6	28.5	7.35	1077.5	87.38	31.1	107.5	7.7	362	152.5	46.5	0.81	690.3	346.2	2.53	41.29	0.3638	47
7	27.75	7.15	757.5	58.27	26.2	82.5	17.5	293	65	37.5	1.35	485.5	253.4	2.25	42.92	0.5819	84
8	28.63	7.39	411.25	53.9	21	71	9.95	249.5	69	47	0.89	263.6	221.1	2.05	40.86	0.6654	125
9	28.75	7.44	1565	77.6	40.6	200	56.75	340	315.5	46.75	1.43	1003	360.7	4.6	58.56	0.1535	12
10	28.38	7.29	985	85.44	25.9	101.3	15	465	49	66.75	1.19	631.1	320	2.44	42.16	1.4786	na
11	28.5	7.5	311.5	26.74	9.87	22.5	3.15	135.5	16.5	19.13	0.51	199.7	107.4	0.93	31.93	1.125	na
12	28.5	7.23	2410	138.5	38.1	350	39	596	428.5	180.6	1.6	1545	502.5	6.74	61.08	0.471	46
13	29.13	7.31	1707.5	90.6	43	152.5	115	318.5	202	112.5	2.67	1094	403.3	3.33	54.56	0.5617	133
14	28.75	7.2	1212.5	91.34	34.9	137.5	36.5	430.5	146	69.75	1.97	777.3	371.8	3.12	48.37	0.4904	82
15	28.63	7.22	1092.5	81.5	29	101.3	46	360.5	107	49.5	2.95	700.3	322.9	2.45	46.28	0.4487	130
16	28.25	7.56	2097.5	95.31	42.3	282.5	134.3	792	226.5	115.5	3.51	1344	411.9	6.03	65.62	0.5113	77
17	28.25	7.33	3137.5	89.33	44	468.8	156.8	816	556.5	100.9	2.32	2010	404.2	10.3	75.25	0.1827	31
18	28.5	7.25	2745	198.2	64.9	226.3	140.5	603.5	354.5	175.1	3.06	1759	761.8	3.58	46.63	0.5086	284
19	28.38	7.19	2750	215.3	84.3	297.5	106.3	668	422	413.8	4.08	1763	884.4	4.36	46.7	1.0464	62
20	28.25	7.21	1260	87.55	41.7	80	70.5	398	122	51	3.09	807.6	390.3	1.76	40.38	0.4174	132
21	28.5	7.19	562.5	61.46	25.9	42.5	17.38	258	36	31.75	1.04	360.7	260.1	1.11	29.98	0.9845	101
22	28.75	7.31	2002.5	111.5	49.4	285	27.75	717	250	107.5	3.94	1283	481.6	5.76	57.29	0.4244	263
23	29.13	7.4	1576.2	49.38	25.4	118.5	12.63	330.5	108.5	60.63	2.28	1010	227.9	3.05	42.75	0.6576	136
24	28.63	7.57	695	37.64	23.9	75	41.5	239.5	98	46.88	1.91	445.5	192.2	2.36	53.65	0.501	114
25	28.25	7.21	3332.5	220.2	68.4	397.5	20.25	383.5	757	160.4	3.14	2136	831.1	6.07	52.66	0.2417	130
26	28.25	7.24	2365	86.08	51.7	332.5	112.5	723.5	309	139.9	3.01	1516	427.7	7.04	66.85	0.4633	30
27	28.75	7.1	1562.5	78.13	39.7	213.8	79.75	468.5	230.5	127	4.75	1002	358.5	5.2	62.75	0.5557	86
28	28.75	7.11	1215	85.41	30.1	97.5	34.5	181.5	170	96.38	5.43	778.6	336.9	2.29	43.66	0.5672	345
29	28.63	7.24	516.25	52.17	24.6	21	6.375	209.5	37	24.63	3.86	330.9	231.5	0.6	18.75	0.6392	68
A	26.83	7.62	1294.6	101	69.7	133.3	5.667	296	204	156.8	1.25	830.3	539.2	2.52	35.75	0.7863	na
B	27.17	7.17	929.3	60.67	30.4	88.33	24.67	240.7	85.33	71.5	2.48	595.8	276.5	2.31	44.68	0.8422	na
C	26.83	6.91	1040.3	68.67	27.5	98.33	14.67	230.7	136	45	2	667	284.5	2.54	43.8	0.3417	na
D	26.83	7.28	1581.6	75.46	50.3	276.7	27.33	339.3	261.3	137.5	7.23	1014	395.3	6.09	61.83	0.5312	na
E	26.83	7.66	662	44.24	24.7	86.67	21.67	255.3	46.67	63.5	1.87	424.3	212.2	2.58	50.11	1.3731	na
F	27	7.37	825	57.3	36.6	35.33	37	326	52	29	0.77	528.2	293.6	0.94	29.13	0.7847	na
G	27.17	7.39	2200	69.4	65.6	558.3	77	640	694.7	154.3	2.49	1412	443.3	11.6	74.84	0.2259	na
H	26.83	7.45	2383.3	80.41	55.6	625	25.67	664.7	801.3	143.5	3.91	1529	429.4	13.1	76.28	0.1813	na
I	27.5	7.22	1450	106.6	51.2	258.3	57	382	362.7	123.5	3.73	930.2	476.8	5.15	57.14	0.3456	na
J	26.83	7.32	1394.3	101	47.9	161.7	75	394	188	101.5	3.41	894.3	449.4	3.33	49.97	0.5452	na
K	26.83	7.27	1166.6	72.6	46.5	276.7	36	490	260	79.17	1.83	748.3	372.5	6.2	63.13	0.3281	na
L	26.83	7.13	591.6	50.18	16.5	55	8.333	188.7	54	45.5	1.5	379.5	193.3	1.7	39.09	0.8408	na
M	26.83	7.53	513	47.58	21.2	41	1.067	214.7	34.67	25	1.39	328.9	205.9	1.24	30.51	0.7396	na
N	26.83	6.99	506.6	30.82	13.6	83	5.6	178	70.67	17	1.2	325	133	3.32	59.15	0.2231	na
O	26.83	7.43	851.6	46	15.5	125	5.433	257.3	112	13.5	7.49	546	178.8	4.11	60.36	0.113	na
P	26.83	7.5	1186	80.07	38.1	155	4.667	352	188	51	2.27	760.5	356.9	3.61	48.55	0.2782	na

NO_3 = concentrations are in the month of Nov. 1999
na = data not avaialable

Table No 2. Comparison of Hydrochemical analysis of groundwater samples collected from Dug wells and Filter points during the year 1997

Month & Type of Well	Temp. ^0C	pH	EC (μmoh/cm)	TDS	TH	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{-2}	PO_4^{-3}
						Average values in ppm							
Feb. 97 & Dug Wells (29 Nos.)	26.8	7.3	1639	1049	376	90	37	173	62	440	199	108	2
May 97 & Dug Wells (29 Nos.)	30.6	7.2	1693	1083	357	87	34	182	52	431	216	89	1.5
Filter points (16 Nos.)	24.5	7.3	1117	715	343	76	37	202	30	369	226	77	0.9
Aug. 97 & Dug Wells (29 Nos.)	29.5	7.3	1567	1005	440	112	39	198	49	465	249	102	4.4
Filter points (16 Nos.)	29.3	7.3	1203	772	311	63	37	205	22	354	216	77	4.1
Nov. 97 & Dug Wells (29 Nos.)	27.0	7.3	1430	918	432	96	47	186	73	395	239	105	1.0
Filter points (16 Nos.)	27.0	7.2	1163	746	329	66	40	166	29	299	224	82	3.4

Table. 3 Classification of Groundwater Samples in the Study Area

Well No.&		Stiff Classification		Piper Classification		U.S.Salinity Lab Classification	
Label	Location	May-97	Nov-97	May-97	Nov-97	May-97	Nov-97
1	Sarpavaram	$CaHCO_3$	$NaHCO_3$*	II	II	C3-S1	C3-S1
2	Balaji Nagar	$NaHCO_3$	$NaHCO_3$	III	II*	C3-S1	C3-S1
3	Valasapakala	$NaHCO_3$	$NaHCO_3$	II	II	C4-S1	C4-S1
4	Vakalpudi	$NaHCO_3$	$NaHCO_3$	III	III	C3-S1	C3-S1
5	Ramanayya Peta	$NaHCO_3$	$NaHCO_3$	III	III	C3-S1	C3-S1
6	R.R. Nagar	$CaHCO_3$	$NaHCO_3$*	I	III*	C3-S1	C2-S1*
7	Madhav Nagar	$CaHCO_3$	$NaHCO_3$*	I	III*	C2-S1	C3-S1*
8	Nagamallithota	$NaHCO_3$	$NaHCO_3$	III	III	C2-S1	C2-S1
9	Godarigunta	$NaHCO_3$	$NaHCO_3$	II	III*	C3-S1	C3-S1
10	Sambamurthy Nagar	$NaHCO_3$	$CaHCO_3$*	III	I*	C3-S1	C2-S1*
11	Shanti Nagar	$NaHCO_3$	$NaHCO_3$	I	I	C2-S1	C2-S1
12	Perraju Peta	$NaHCO_3$	$NaHCO_3$	II	II	C4-S1	C3-S1*
13	Kondayya Palem	$NaHCO_3$	$NaHCO_3$	II	III*	C3-S1	C3-S1
14	Gandhi Nagar	$NaHCO_3$	$NaHCO_3$	III	III	C3-S1	C3-S1
15	Rama Rao Peta	$NaHCO_3$	$NaHCO_3$	III	III	C3-S1	C3-S1
16	Surya Rao Peta	$NaHCO_3$	$NaHCO_3$	III	III	C4-S1	C3-S1*
17	Suryanarayana Prm	$NaHCO_3$	$NaHCO_3$	III	III	C4-S2	C4-S1*
18	Budam Peta	$NaHCO_3$	$NaHCO_3$	III	II*	C4-S2	C4-S1*
19	Temple Street	$NaHCO_3$	NaCl*	II	II	C4-S1	C4-S1
20	Frazer Peta	$NaHCO_3$	$CaHCO_3$*	III	III	C3-S1	C3-S1
21	Pratap Nagar	$CaHCO_3$	$CaHCO_3$	I	I	C2-S1	C2-S1
22	Jagannadha Puram	$NaHCO_3$	$NaHCO_3$	VI	III*	C3-S1	C3-S1
23	Gogudanayya Peta	$NaHCO_3$	$CaHCO_3$*	III	I*	C3-S1	C2-S1*
24	M.S.N.Charties	$NaHCO_3$	$NaHCO_3$	III	III	C2-S1	C3-S1*
25	Turangi	NaCl	NaCl	II	II	C4-S1	C4-S1
26	Paradesamma Peta	$NaHCO_3$	$NaHCO_3$	III	III	C4-S1	C3-S1*
27	Indra Palem	$NaHCO_3$	$NaHCO_3$	III	III	C3-S1	C3-S1
28	Chidiga	$NaHCO_3$	$NaHCO_3$	II	III*	C3-S1	C3-S1
29	Madhura Nagar	$CaHCO_3$	$NaHCO_3$*	I	I	C2-S1	C2-S1
A	Madhura Nagar	$NaHCO_3$	$NaHCO_3$	I	I	C3-S1	C3-S1
B	Gandhi Nagar	$NaHCO_3$	$NaHCO_3$	III	III	C3-S1	C3-S1
C	Indra Palem	$CaHCO_3$	$NaHCO_3$*	I	I	C3-S1	C3-S1
D	Suryarao Peta	$NaHCO_3$	$NaHCO_3$	II	II	C3-S1	C3-S1
E	M.S.N.Charties	$NaHCO_3$	$NaHCO_3$	III	III	C3-S1	C2-S1*
F	Jagannadha Puram	$CaHCO_3$	$NaHCO_3$*	I	I	C3-S1	C2-S1*
G	Suryanarayana Prm	NaCl	NaCl	II	II	C3-S2	C4-S2*
H	Sambamurthy Nagar	NaCl	NaCl	II	II	C3-S2	C4-S2*
I	Bhanugudi	NaCl	$NaHCO_3$*	II	II	C3-S1	C3-S1
J	Town Rly.Station	$NaHCO_3$	$NaHCO_3$	III	III	C3-S1	C3-S1
K	Godarigunta	$NaHCO_3$	$NaHCO_3$	III	II*	C3-S1	C2-S1*
L	Sarpavaram	$NaHCO_3$	$NaHCO_3$	I	III*	C2-S1	C2-S1
M	Nagamallithota	$CaHCO_3$	$CaHCO_3$	I	I	C2-S1	C2-S1
N	Balaji Nagar	$NaHCO_3$	$NaHCO_3$	I	III*	C2-S1	C3-S1*
O	Vakalpudi	$NaHCO_3$	$NaHCO_3$	III	II*	C3-S1	C3-S1
P	R.R. Nagar	$NaHCO_3$	$NaHCO_3$	III	I*	C3-S1	C3-S1

* = Change in Classification from pre monsoon to post monsoon period

I = $Ca(HCO_3)_2$ II = NaCl III = Mixed $CaNaHCO_3$

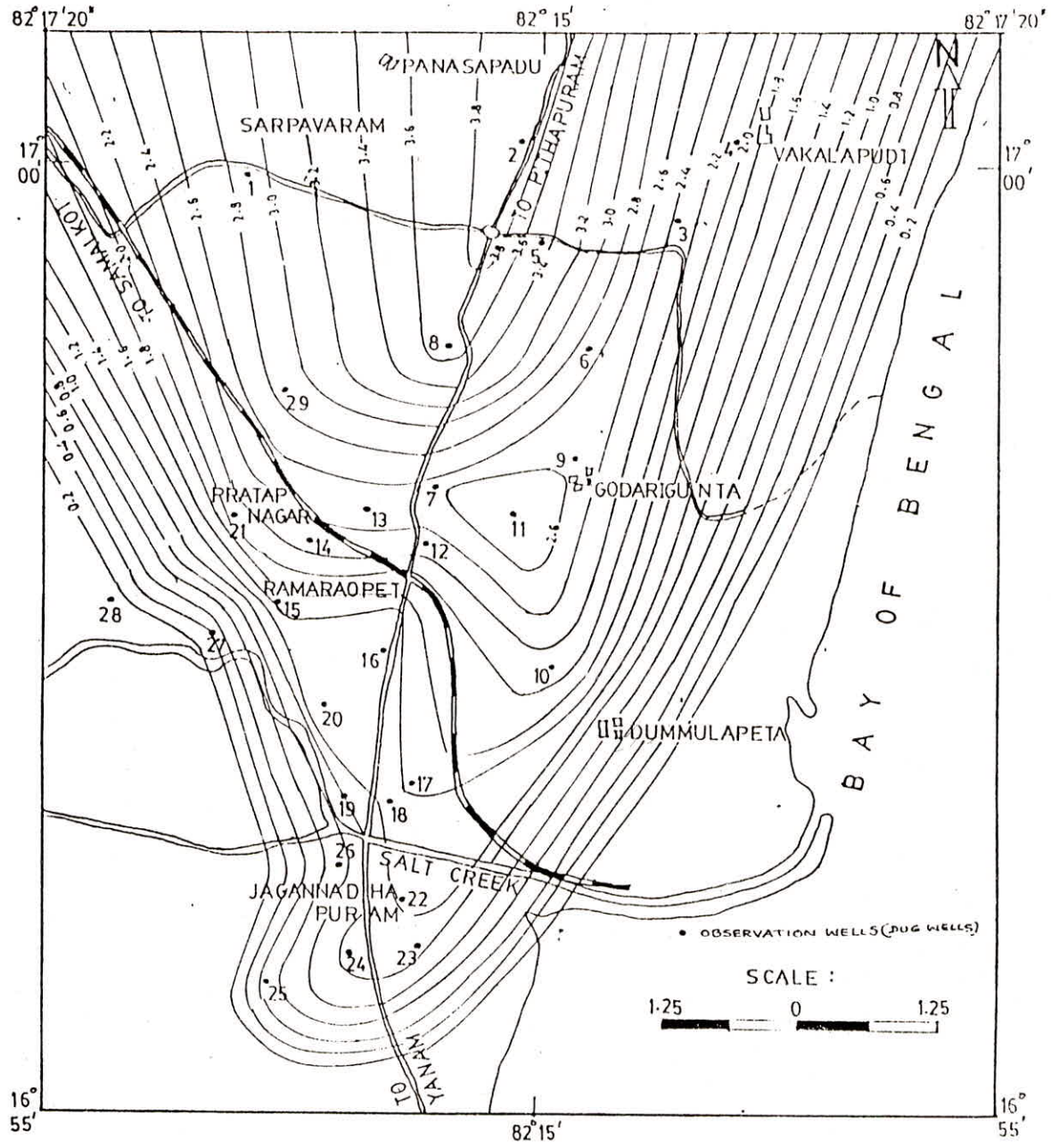

Fig. 2 : Groundwater Level Contours (Above MSL in Mts) in the Month of April 1997

5.0 CONCLUSIONS

Total 164 groundwater samples were collected in four surveys during the months of Feb.97, May 97, Aug. 97 and Nov. 97 respectively. These samples were analysed for their physical and chemical parameters. The dominant cation and anion in the study area are Sodium and Bicarbonate respectively. Based on SAR and %Na values the study area falls under medium hazard of sodium. The range of total hardness indicates that the groundwater quality is under hard to very hard zone. The comparison of water quality parameters with ISI maximum permissible drinking water standards gives an indication that it is always advisable to tap groundwater through filter points in the study area, especially for drinking water purposes. The high values of SO_4/Cl ratio indicate the impact of fertiliser use on groundwater in the study area. Detailed investigations are necessary to study the groundwater quality variations at different depths and sources of high Nitrate concentrations in the shallow aquifer. The groundwater flow direction is towards saltcreek and Bay of Bengal.

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